Chapter 3
Defining Base Conditions

3-1. Overview

The initial task in evaluating the feasibility of a flood warning - preparedness program is to define the base year conditions. Base conditions refers to the year the project will go on-line. In some cases, base year conditions will be different from existing or current year conditions. The base conditions form the baseline for evaluation of incremental enhancements to flood damage mitigation strategies for flood warning - preparedness programs. The expected magnitude and frequency of flooding, the populations (people and structures) at risk, and the institutions involved in emergency management all require evaluation.

3-2. Flood Hazard Analysis

a. General. Hydrologic engineering investigations are conducted to define the flood hazard and to develop information for economic analysis of existing and proposed improved conditions as required for evaluation of any flood damage reduction measure. The flood hazard is defined by the frequency and location of flooding in addition to the depth, duration, and velocity of the floodwater. The information required includes discharge-frequency and stage-discharge relationships, flood inundation boundary maps, and flood warning time. The level of detail must be commensurate with the overall scope of the investigation, allocated time, and resources. Flood hazard data available from previous water resources investigations and developed for evaluation of other alternatives are used to the extent possible.

b. Hydrologic analysis. The hydrologic analysis required for defining the base condition flood hazard consists of traditional, standard procedures that are well documented in Corps' publications. EM 1110-2-1419 describes general hydrologic requirements for flood damage reduction studies. Elements of the hydrologic analysis that are important for flood warning - preparedness programs and are described below.

(1) Flood hydrograph development. Flood hydrographs are developed at key locations to define the magnitude and timing of flood flow. The relationship between rainfall and runoff helps define warning times. A watershed rainfall-runoff model such as the HEC-1 program (U.S. Army Corps of Engineers (USACE) 1982b) is generally used to develop the flood hydrographs. Historic and hypothetical frequency events are selected for evaluation based on available stream flow records, rainfall records, high water marks, etc. The analysis involves developing runoff parameters from gaged data and the calibration of rainfall and runoff parameters for each of the selected historic flood events. The model will also be calibrated using the hypothetical events to gaged frequency statistics. If there are no stream gages in the watershed of interest, the analysis may include modeling of nearby, similar-gaged watersheds and extrapolation of parameters. The assumption is that at least some recording stream gage data are available in or near the study watershed. If no data are available, synthetic unit hydrograph parameters can be developed and applied, based on watershed time-of-concentration. These parameters can be used to develop flood hydrographs from hypothetical frequency storm data published by the NWS.

(2) Warning time. An important element of the flood warning - preparedness plan is the warning time available to residents subject to flooding. Warning time determines how much time a threatened population has to respond to a specific event and, therefore, the amount of flood damage reduction activities that can take place. The purpose of a flood recognition system is to provide a means of increasing the warning time and its reliability. This is accomplished by reducing flood recognition and reaction time and allowing more time to carry out response actions. These times must be defined to evaluated potential enhancements that increase warning time. Figure 3-1 shows warning time for a representative storm event and for a specific threatened property location (flood stage). This type of relationship can be developed for different flood stages and locations as appropriate for identified threatened properties. Mathematically, warning time can be described as:

$$T_W = T_{WP} - T_R \tag{3-1}$$

where

T_W = actual warning time

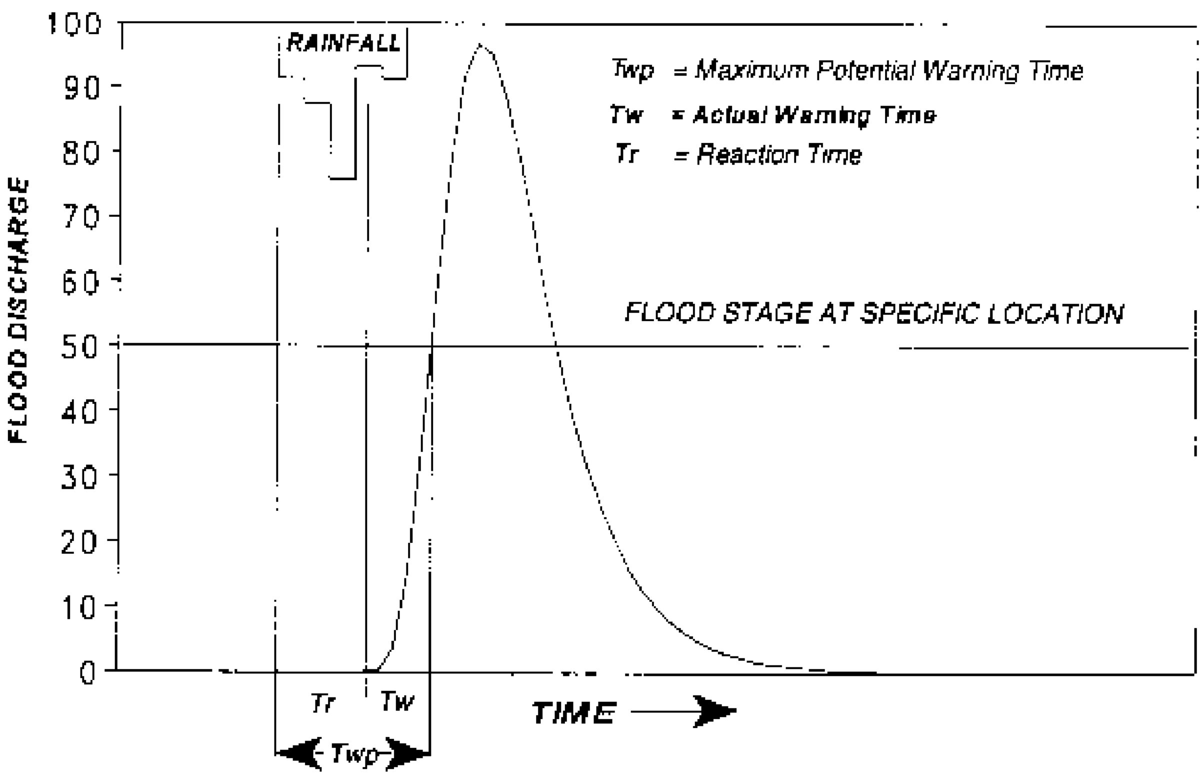
T_{WP} = maximum potential warning time

T_R = flood threat recognition/reaction time

(a) The maximum potential warning time is defined herein as the time from the beginning of the storm event to the time that the stream reaches flood stage.

(b) The flood recognition and reaction time, T_R, includes the time required to observe or measure developing conditions, T_{obs}, the time needed to acquire the necessary data, T_{data}, the time required to analyze the storm data and determine (recognize) that a flood is likely to occur and to prepare a forecast, T_{fp}, and the time required to disseminate the flood warning, T_{dis}. The flood recognition and reaction time can be expressed as:

$$T_R = T_{obs} + T_{data} + T_{fp} + T_{dis} \tag{3-2}$$



(c) The time needed to observe the developing event, T_{obs} , is a balance between waiting long enough to get enough information to accurately determine the flood threat and acting soon enough to have a valuable forecast. A reasonable estimate of T_{obs} is about 15 to 25 percent of the time of concentration of the watershed, depending on how the data are observed.

$$0.25T_c \geq T_{obs} \geq 0.15T_c \quad (3\text{-}3)$$

(d) Maximum warning times can be estimated using any one of several techniques. The most appropriate technique is to examine flood hydrographs developed from historical and hypothetical storm events. The range and variability of flood warning time at key locations should be determined based on the hydrologic simulation of historical and hypothetical storm events. Events should include the variation of rainfall intensity and distribution as well as antecedent conditions likely to be encountered in the watershed. Warning time will vary depending on the location (elevation) of damageable properties in the floodplain. Properties with common warning times should be grouped and response actions defined based on the warning time.

(e) The time from the onset of rainfall to the critical flood stages is determined directly from each event. If the distribution of maximum potential warning times of the set of critical hydrographs is highly variable, then many events could have maximum potential warning times significantly less than the mean. In those cases, a lower value may be chosen as a more realistic and conservative estimate of maximum potential warning time.

(f) All flood warning - preparedness programs should include stream stage monitoring (stages and rates of rise) near the locations where response actions are required. This should include a staff gage and more sophisticated systems as applicable. Additional warning time may be obtained by monitoring upstream conditions. Stream monitoring is always desirable and significantly more reliable than rainfall data. However, for small flash flood conditions, rainfall monitoring is normally required to extend the warning time.

(g) The continuous monitoring of the system enables the preparedness actions to be implemented in predetermined phases. The initial phase may be that the officials are alerted of a potential flood threat. The next phase may require that they are assigned to key locations in the filed as observers and readily available for specific emergency actions. Subsequent phases might implement actions of emergency response for the general public and maintenance of vital services. The greater and more reliable the warning time, the more effective the emergency response actions become.

(h) Dotson and Peters (1990) provide an example of how to estimate warning times and select the upstream threshold stage to trigger flood warnings. The first step is to obtain stream flow data from historical records or simulated data from a computer model such as HEC-1 for the location where warnings are required. Stream flow data are also needed for selected upstream locations that are under consideration for use as a trigger or index for downstream flood warnings. Next, the stage and/or flow associated with the point where flood damage begins at the downstream location is defined. Flood records are then analyzed, and the set of occurrences where flood flows are exceeded at the downstream location are determined. Upstream records are analyzed for threshold values of upstream flow that can be used to forecast the occurrence of downstream flooding. Different potential upstream threshold values are tested to determine warning time provided and the percentage of accurate flood warnings provided.

(i) Typically, there is an inverse relationship between increased warning times and the percentage of correct forecasts. Selecting a lower upstream threshold generally increases the warning time, but the percentage of correct forecasts decreases. Conversely, selection of a higher threshold increases the percentage of correct forecasts but decreases the warning time available. In an example provided by Dotson and Peters (1990), selection of a 5.66 cms (200-cfs) upstream threshold yielded correct forecasts 36 percent of the time and at least 30-min warning times 69 percent of the time. Selection of a threshold value of 11.33 cms (400 cfs) increased the percentage of correct forecasts to more than 80 percent, but the percentage of forecasts with more than 30 min of warning dropped to about 40 percent.

(3) Observed storm patterns. The types of storms and flood trigger mechanisms must be identified. Types of storms include thunderstorms, frontal storms, winter storms, summer storms, snow-melting events, and hurricanes. The flood triggering event can be rainfall, snowmelt, ice jams, dam failure, large or small rivers and can be involved. The type of situation involved defines the flood warning - preparedness required. Table 3-1 lists the type of monitoring condition, the typical measurements desired, and the general hardware applicable for various types of streams.

c. Hydraulic analysis. Hydraulic analysis is needed to determine water surface profiles, study reaches, and channel routing criteria. EM 1110-2-1416 describes general requirements for flood damage reduction studies. Water surface profiles are developed for the historic events of interest and a range of hypothetical frequency events. The analysis results in a series of rating curves at desired locations (and water surface profiles) that may be used to determine discharge for various levels (stages) of flooding at key locations throughout the watershed. The extent of flooding is also used to develop flood inundation boundaries for selected events and information of depths and velocities throughout the study area.

(1) Flood inundation maps. The extent of flooding or area inundated is part of the information required to define the flood hazard. This is determined by defining the boundaries of inundation for selected flood levels for the study reach. Flood inundation maps are important for developing appropriate warning dissemination procedures and response actions for various levels of flooding. Results of the water surface profile computations, described above, can be used to determine the longitudinal water surface profile along the reach under study. The areas inundated are identified on a topographical map using the water surface profiles associated with a range of stages as defined by the hydraulic analyses. Once these areas of inundation are determined, then warning dissemination messages and methods can be determined, threatened properties identified, impacted vital services (traffic, power, gas, water, sanitary, etc.) determined, egress routes identified, and locations for specific flood fighting efforts defined.

(2) Depth-velocity. Combinations of depths and velocities of water pose a serious physical rise to people during flood events. Shallow flooding with high velocities often pose an unrecognized but greater threat than deeper slower flowing streams. Table 3-2 shows the risk associated with various combinations of flood depths and velocities.

Flood damages occur due to the depth of water and velocity of the water. The duration may also be a factor. Some materials (e.g., carpeting, food supplies, dry goods inventory, etc.) are damaged with direct contact with the water. Other damage occurs due to hydrostatic pressures caused by high water (e.g., roadways, basement walls, swimming pools, etc.). Buoyant forces can cause cars, storage tanks, mobile homes, and any other unsecured objects to float away. Other damages are velocity related. High velocities also

Table 3-1
Flood-threat Recognition Monitoring Systems

Monitoring Conditioning	Preliminary Measurements Obtained	Monitoring System: Small/Steep Streams	Monitoring System: Moderate Streams	Monitoring System: Large Rivers
Precipitation				
1. Thunderstorms Cloudbursts Rainfall	Rainfall intensity	Network of Regional Recording Raingages	Network of Regional/ Watershed Recording Raingages	Generally not applicable, available system acceptable
2. General-Steady Rainfall	Rainfall intensity & distribution	Network of Regional/ Watershed Recording Raingages	Mix of Regional/ Watershed Recording, Daily, and Field Observed Raingages	Available Raingage System is generally applicable
3. Snow	Snow depth/ moisture content	N/A	N/A	Field measurements, some automatic Recording
Streams				
1. Normal Flowing	Stages/rate-of-rise	Mix of Staff Gages, Upstream and Local Stage Alarms, Continuous Recording Gages	Mix of Staff Gages, Upstream and Local Stage Alarms, Continuous Recording Gages	Staff gages normally acceptable
2. Backwater/ Ponding	Stages/rate-of-rise	Generally N/A	Staff gages, maybe Continuous Recording	Staff gages normally acceptable

Table 3-2
Flood Hazard Rating

Physical Hazard	Low	Medium	High
1% Flood Depth	<0.3 m (1 ft)	0.3-0.9 m (1-3 ft)	>0.9 m (3 ft)
Flood Rise Time	>24 hr	12-24 hr	<12 hr
Flood Velocity	<0.3 ms (1 fts)	0.3 - 0.9 ms (1-3 fts)	>0.9 ms (3 fts)
Flood Duration	<6 hr	6-24 hr	>24 hr
Site Access	good	fair	poor

impact eroded soils around foundations, causing bridges and buildings to collapse. High velocities also sweep away movable objects. These objects can become battering rams and cause further damage downstream.

d. Threatened properties analysis. Flood inundation maps, aerial photographs, field surveys, etc., are used to identify locations where existing properties are threatened by various levels of flooding. Existing damageable structures should be categorized by type and number for each flood event throughout the range of the flood-frequency relationship. Frequency-discharge-elevation-damage relationships are presented in tabular form. The information is used to help in the development of warning and evacuation plans, location of mass care centers, management of vital services, and to estimate the number of structures and people impacted by an event. It is also used in defining areas for potential implementation of temporary flood loss reduction actions such as flood fighting, installation of temporary barriers, and removal or raising contents of structures, and potential hazardous material location. The threatened properties analysis helps refine response measures that might be dictated due to warning time available. The location of structures in the floodplain can determine whether more or less warning time is available. Structure located at lower elevation in the flood-plain generally have less time than structures located at higher elevations. Taking a conservative approach when determining how much time is available is normally better.

3-3. Assessment of Existing Flood Warning - Preparedness Programs

Once the magnitude of the flood hazard is established and the warning times determined, the existing flood warning - preparedness program is defined. Once defined, the program's effectiveness can be evaluated. Program components currently in place are identified. Existing plans and Federal/ local institutional arrangements must form the basis to identify and evaluate needed enhancements. Typically, recent events are investigated to evaluate flood-threat recognition, warning dissemination, and response actions that occurred within existing institutional arrangements and their overall effectiveness.

a. Flood-threat recognition system. The flood-threat recognition systems currently in place, used for monitoring, and in some cases, forecasting, should be the described and include the following.

(1) Observers. Are observers employed to watch streams and/or staff gages at key locations during flood events? If so, identify to whom the observations are reported, and where, when, and how they are used.

(2) Simplified charts or tables. Simple charts and table look-up information may be used to identify a flood threat. If this is the case, determine how the information is obtained and used.

(3) Precipitation and/or water level gages. Existing rain and stream gages in or near the watershed should have been identified during the hydrologic analysis to determine discharge-frequency, stage-discharge, and flood warning times, as previously described. Determine which gages, if any, are used to help assess the flood threat under current arrangements.

(4) Automated self-reporting gage network and data retrieval systems. If an automated reporting gage network is currently used, determine the number, type, and location of the gages. Identify reporting methods, data storage, management, analysis, and displays. Identify key people "in charge" of the network and discuss use, reliability, effectiveness, and maintenance of the system.

If an automated reporting gage network exists, a central location is generally used for data retrieval, storage, and management. This central site is usually referred to as a base station. Hardware usually consists of a data receiver such as a radio antenna or satellite dish and a personal computer (PC) to display and/or process the data. Base station software may include data collection, storage, display, and management software provided and installed by the vender. In addition, a rainfall-runoff forecast model may be part of the system. A description of two popular types of flood recognition data retrieval and processing systems, which are available from the NWS or private vendors, are given below.

(a) ALERT - Automated Local Evaluation in Real Time (ALERT) system was developed by the NWS River Forecast Center in Sacramento, CA. Available from the NWS or private vendors, the ALERT system has been adopted at many locations for flood-threat recognition systems, especially in the western United States. The system typically consists of an automated reporting precipitation and stream gage network and a VHF radio line-of-sight communication system for transmission of data to one or more base stations. The base station consists of radio receiving equipment and a PC microprocessor. Software running on the base station PC can collect, screen, and display precipitation and stream flow data received from the self-reporting gages to monitor the system. Additional software (hydrologic model) is available to forecast events by simulating stream flow from precipitation data.

(b) IFLOWS - The Integrated Flood Observing and Warning System (IFLOWS) consists of a network of automated self-reporting precipitation gages. The line-of-sight radio networks are typically county-wide and usually include several receiving sights so data can be shared among county, state, and NWS officials. Software employed at the receiving sight allows for storing and displaying the precipitation data.

If these types of automated data collection and reporting systems exist, it is important to determine the type of hardware and software installed and how the system is used during a flood event. The consideration of whether the system is used and maintained on a regular bases is important. If the base station includes forecasting capabilities, model software maintenance is vital. Software maintenance includes periodically calibrating/updating parameters and analysis of model results for reliability and accuracy. Maintenance must be carried out by a technical person skilled in the hydrologic aspects of the model and the watershed.

b. Warning dissemination. Existing warning dissemination arrangements must be defined to evaluate enhancements to the system. The role of participating agencies should be described in detail. A detailed description of the flood warning dissemination process describing formal and informal lines of communication, responsible agencies, points of contact, and method of communication should be developed. It is generally good practice to describe the process in both text and schematic form.

c. Response actions. Existing emergency response actions that are normally carried out during a flood event should be described. Consideration should be given to the following when describing the existing situation.

(1) Search, rescue, and evacuation programs.

(2) Law enforcement activities, including traffic control property surveillance and crime prevention.

(3) Fire protection/prevention arrangements.

(4) Emergency medical service, care center, and shelter programs.

(5) Flood emergency utility services protection and maintenance plans.

(6) Flood fighting, protection and damage reduction measures, and programs including relocation and protection of damageable property.

(7) Public information and training programs.

d. Postflood recovery and reoccupation programs. Any postflood recovery and reoccupation programs that are currently in place should be described in detail.

e. Plan and program management, operation, and maintenance programs. Plan management is required to maintain the viability and functionality of the plan components for the relatively long periods that may pass between operation (flood events). Determine whether institutional cooperation agreements and arrangements required for implementation and continued effective operation and maintenance of the existing flood warning - preparedness plan are in place. Determine and document whether these agreements include consideration for the following.

(1) Updating formal lines of communications, personnel assignments, and community maps.

(2) Operation, testing, maintenance, and replacement of hardware and software.

(3) Continued practice drills, education, and training of responsible community officials and the general public.

f. Institutional arrangements. Institutional arrangements are formal and informal organizational arrangements for communication, coordination, and conduct of operations required to implement a flood warning - preparedness plan. Specifically, the institutional analysis defines the existing processes for information collection, analysis, and dissemination for each plan component. The organizational authorities, responsibilities, and general capabilities to carry out potential plan enhancements must also be determined.

(1) The time required for local institutions to recognize a flood threat and to disseminate a warning to their constituents is an important consideration. The hydrologic analysis that determined the potential warning time for a community sets the boundary conditions within which the institutions must operate. If institutions cannot meet their stated goals within the time frames dictated by the local hydrologic conditions, the deficiencies must be noted and used to formulate enhancement strategies.

(2) Five criteria (Neal and Lee 1988) can be used to determine the overall effectiveness of institutional response to flooding.

(a) Experience. Institutional experience that helps improve future response comes from several sources:

- Recent flood experience heightens community awareness. It also draws agencies together in a postflood analysis to create an improved working plan.

- Recent disaster experience also works to improve future response. Even if the disaster was unrelated to a flood event, the experience of emergency officials working together builds relationships that help make a more efficient response to future events.

- Exercises and drills allow emergency personnel to think through disaster scenarios and potential problems. A history of drills and exercises in the community often suggests that the key agencies will function together properly when an emergency strikes.

- Up-to-date emergency plans indicate that the community has made an investment in preparedness and, at least, has thought through the response process.

(b) Networks. Organizations generally work together better if their representatives know each other. Frequent contact between the key response agencies during interevent periods usually creates a more efficient response operation.

(c) Decision-making. Effective decision-making is crucial for effective response. Information must get to the proper place accurately and in a timely fashion. Flexibility and participatory command and control can aid decision-making during emergency operations.

(d) Communication. Interagency communication is a key success parameter in emergency response situations. Any communication delay inhibits effective decision-making. Communication within the organization is equally important. Field staff and headquarters staff must communicate frequently and accurately. Internal problems can delay warning messages just as effectively as external communications problems.

(e) Everyday/disaster task overlap. Organizations who experience emergencies on a daily basis respond better during a flood emergency than agencies who do not. The National Weather Service, U.S. Army Corps of Engineers, police, fire, and sheriff's departments are ideal organizations to include on the emergency response team.

A thorough review of these institutional dynamics will provide insight into the effectiveness of the current response systems and provide insights into what enhancements are necessary.

g. *Economic evaluation*. The economic study for base conditions of a flood warning - preparedness program is primarily accomplished using information generated for flood damage reduction investigations. The base without project conditions flood hazard and flood damage are used. The feasibility phase studies, the reconnaissance phase level of detail is normally appropriate. If other plans are not feasible, flood warning - preparedness programs may be moved forward under the Continuing Authority Section 205 program. The procedures are defined in ER 1105-2-100.